An **alloy** is a mixture of chemical elements of which at least one is a metal. Unlike chemical compounds with metallic bases, an alloy will retain all the properties of a metal in the resulting material, such as electrical conductivity, ductility, opacity, and luster, but may have properties that differ from those of the pure metals, such as increased strength or hardness. In some cases, an alloy may reduce the overall cost of the material while preserving important properties. In other cases, the mixture imparts synergistic properties to the constituent metal elements such as corrosion resistance or mechanical strength.

In an alloy, the atoms are joined by metallic bonding rather than by covalent bonds typically found in chemical compounds.[1] The alloy constituents are usually measured by mass percentage for practical applications, and in atomic fraction for basic science studies. Alloys are usually classified as substitutional or interstitial alloys, depending on the atomic arrangement that forms the alloy. They can be further classified as homogeneous (consisting of a single phase), or heterogeneous (consisting of two or more phases) or intermetallic. An alloy may be a solid solution of metal elements (a single phase, where all metallic grains (crystals) are of the same composition) or a mixture of metallic phases (two or more solutions, forming a microstructure of different crystals within the metal).

Examples of alloys include red gold (gold and copper), white gold (gold and silver), sterling silver (silver and copper), steel or silicon steel (iron with non-metallic carbon or silicon respectively), solder, brass, pewter, duralumin, bronze, and amalgams. Meteorites are sometimes made of naturally occurring alloys of iron and nickel, but are not native to the Earth.

One of the first alloys made by humans was bronze, which is a mixture of the metals tin and copper. Bronze was an extremely useful alloy to the ancients, because it is much stronger and harder than either of its components. Steel was another common alloy. However, in ancient times, it could only be created as an accidental byproduct from the heating of iron ore in fires (smelting) during the manufacture of iron.

Alloys are used in a wide variety of applications, from the steel alloys, used in everything from buildings to automobiles to surgical tools, to exotic titanium alloys used in the aerospace industry, to beryllium-copper alloys for non-sparking tools.

An alloy is a mixture of chemical elements, which forms an impure substance (admixture) that retains the characteristics of a metal. An alloy is distinct from an impure metal in that, with an alloy, the added elements are well controlled to produce desirable properties, while impure metals such as wrought iron are less controlled, but are often considered useful. Alloys are made by mixing two or more elements, at least one of which is a metal. This is usually called the primary metal or the base metal, and the name of this metal may also be the name of the alloy. The other constituents may or may not be metals but, when mixed with the molten base, they will be soluble and dissolve into the mixture. The mechanical properties of alloys will often be quite different from those of its individual constituents. A metal that is normally very soft (malleable), such as aluminium, can be altered by alloying it with another soft metal, such as copper. Although both metals are very soft and ductile, the resulting aluminium alloy will have much greater strength. Adding a small amount of non-

metallic carbon to iron trades its great ductility for the greater strength of an alloy called steel. Due to its very-high strength, but still substantial toughness, and its ability to be greatly altered by heat treatment, steel is one of the most useful and common alloys in modern use. By adding chromium to steel, its resistance to corrosion can be enhanced, creating stainless steel, while adding silicon will alter its electrical characteristics, producing silicon steel.

Like oil and water, a molten metal may not always mix with another element. For example, pure iron is almost completely insoluble with copper. Even when the constituents are soluble, each will usually have a saturation point, beyond which no more of the constituent can be added. Iron, for example, can hold a maximum of 6.67% carbon. Although the elements of an alloy usually must be soluble in the liquid state, they may not always be soluble in the solid state. If the metals remain soluble when solid, the alloy forms a solid solution, becoming a homogeneous structure consisting of identical crystals, called a phase. If as the mixture cools the constituents become insoluble, they may separate to form two or more different types of crystals, creating a heterogeneous microstructure of different phases, some with more of one constituent than the other. However, in other alloys, the insoluble elements may not separate until after crystallization occurs. If cooled very quickly, they first crystallize as a homogeneous phase, but they are supersaturated with the secondary constituents. As time passes, the atoms of these supersaturated alloys can separate from the crystal lattice, becoming more stable, and forming a second phase that serves to reinforce the crystals internally.

Alloying elements are added to a base metal, to induce hardness, toughness, ductility, or other desired properties. Most metals and alloys can be work hardened by creating defects in their crystal structure. These defects are created during plastic deformation by hammering, bending, extruding, et cetera, and are permanent unless the metal is recrystallized. Otherwise, some alloys can also have their properties altered by heat treatment. Nearly all metals can be softened by annealing, which recrystallizes the alloy and repairs the defects, but not as many can be hardened by controlled heating and cooling. Many alloys of aluminium, copper, magnesium, titanium, and nickel can be strengthened to some degree by some method of heat treatment, but few respond to this to the same degree as does steel.

When a molten metal is mixed with another substance, there are two mechanisms that can cause an alloy to form, called *atom exchange* and the *interstitial mechanism*. The relative size of each element in the mix plays a primary role in determining which mechanism will occur. When the atoms are relatively similar in size, the atom exchange method usually happens, where some of the atoms composing the metallic crystals are substituted with atoms of the other constituent. This is called a *substitutional alloy*. Examples of substitutional alloys include bronze and brass, in which some of the copper atoms are substituted with either tin or zinc atoms respectively.

In the case of the interstitial mechanism, one atom is usually much smaller than the other and can not successfully substitute for the other type of atom in the crystals of

the base metal. Instead, the smaller atoms become trapped in the interstitial sites between the atoms of the crystal matrix. This is referred to as an *interstitial alloy*. Steel is an example of an interstitial alloy, because the very small carbon atoms fit into interstices of the iron matrix.

Stainless steel is an example of a combination of interstitial and substitutional alloys, because the carbon atoms fit into the interstices, but some of the iron atoms are substituted by nickel and chromium atoms.

Electrum is a naturally occurring alloy of gold and silver,[1][2] with trace amounts of copper and other metals. Its color ranges from pale to bright yellow, depending on the proportions of gold and silver. It has been produced artificially and is also known as "green gold".[3]

Electrum was used as early as the third millennium BC in Old Kingdom of Egypt, sometimes as an exterior coating to the pyramidions atop ancient Egyptian pyramids and obelisks. It was also used in the making of ancient drinking vessels. The first known metal coins made were of electrum, dating back to the end of the 7th century or the beginning of the 6th century BC.

An alloy is technically an impure metal, but when referring to alloys, the term *impurities* usually denotes undesirable elements. Such impurities are introduced from the base metals and alloying elements, but are removed during processing. For instance, sulfur is a common impurity in steel. Sulfur combines readily with iron to form iron sulfide, which is very brittle, creating weak spots in the steel.[2] Lithium, sodium and calcium are common impurities in aluminium alloys, which can have adverse effects on the structural integrity of castings. Conversely, otherwise pure-metals that contain unwanted impurities are often called "impure metals" and are not usually referred to as alloys. Oxygen, present in the air, readily combines with most metals to form metal oxides; especially at higher temperatures encountered during alloying. Great care is often taken during the alloying process to remove excess impurities, using fluxes, chemical additives, or other methods of extractive metallurgy.

Alloying a metal is done by combining it with one or more other elements. The most common and oldest alloying process is performed by heating the base metal beyond its melting point and then dissolving the solutes into the molten liquid, which may be possible even if the melting point of the solute is far greater than that of the base. For example, in its liquid state, titanium is a very strong solvent capable of dissolving most metals and elements. In addition, it readily absorbs gases like oxygen and burns in the presence of nitrogen. This increases the chance of contamination from any contacting surface, and so must be melted in vacuum induction-heating and special, water-cooled, copper crucibles.[4] However, some metals and solutes, such as iron and carbon, have very high melting-points and were impossible for ancient people to melt. Thus, alloying (in particular, interstitial alloying) may also be performed with one or more constituents in a gaseous state, such as found in a blast furnace to make pig iron (liquid-

gas), nitriding, carbonitriding or other forms of case hardening (solid-gas), or the cementation process used to make blister steel (solid-gas). It may also be done with one, more, or all of the constituents in the solid state, such as found in ancient methods of pattern welding (solid-solid), shear steel (solid-solid), or crucible steel production (solid-liquid), mixing the elements via solid-state diffusion.

By adding another element to a metal, differences in the size of the atoms create internal stresses in the lattice of the metallic crystals; stresses that often enhance its properties. For example, the combination of carbon with iron produces steel, which is stronger than iron, its primary element. The electrical and thermal conductivity of alloys is usually lower than that of the pure metals. The physical properties, such as density, reactivity, Young's modulus of an alloy may not differ greatly from those of its base element, but engineering properties such as tensile strength,[5] ductility, and shear strength may be substantially different from those of the constituent materials. This is sometimes a result of the sizes of the atoms in the alloy, because larger atoms exert a compressive force on neighboring atoms, and smaller atoms exert a tensile force on their neighbors, helping the alloy resist deformation. Sometimes alloys may exhibit marked differences in behavior even when small amounts of one element are present. For example, impurities in semiconducting ferromagnetic alloys lead to different properties.

Rearden metal is a fictitious metal alloy invented by Hank Rearden. It is lighter than traditional steel but stronger, and is to steel what steel was to iron. It is described as greenish-blue. Among its ingredients are iron and copper.